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An Assessment of the Long Term Irrigation Planning Program

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Summary

The irrigation planning program (IPP), which evaluates any specified irrigation schedule over a standard twenty year period, was assessed against applied irrigation on main crop potatoes at Gleadthorpe Experimental Husbandry Farm.

On the twenty year average, the amount of irrigation predicted by the program was in close agreement with that actually applied. However, for individual years there were differences of 1 to 3 applications, each of 25mm.

The quantity of summer drainage calculated by the program compared favourably with MORECS data from Gleadthorpe, giving further confirmation that the irrigation planning program produces realistic long term estimates for water requirement - at least for potatoes.

There are still several areas where the program could be further improved, vis a vis specification of crop and soil parameters, output statistics and better use of existing data bases. This memorandum explores these suggestions.

The values produced by the program represent an idealised situation as no account can be taken of other pressures on time and resources on a grower, nor of his reaction to weather forecast advice.

Introduction

Originally, long term irrigation advice was based on broadscale climatologies ie Hogg (1967), MAFF (1967) which provided general information on inflexible irrigation plans for a single crop - grassland. In an innovative attempt to make a plan more farm-specific, Field (1982) devised a program where crop characteristics, soil available water capacity (AWC) and locally adjusted rainfall could be combined with an individual irrigation plan to produce monthly and annual estimates of irrigation need. The results were consistent with the earlier works but an independent assessment against actual water use was not undertaken.

Gleadthorpe EHF has been conducting potato irrigation experiments for thirty years. The water has been applied following the method of Adams and McClean (unpublished) and MAFF (1984) - the daily balance sheet method - for the majority of years. It is not to be expected that these two different schemes will produce identical results, but a comparison is made and the differences discussed.

Results

1. Comparison of Program Estimates with Gleadthorpe Applied Irrigation.

   The IPP was run for main crop potatoes at Gleadthorpe EHF for the program's standard period 1961-80. The other specifications for the run were*

   a) irrigation plan: apply 25mm at a deficit of 35mm between 1/6 and 30/8.

   b) "medium" AWC soil - 17% by volume in the program, corresponding to the sandy loam over loamy sand soil at Gleadthorpe.

c) crop planted 20/4, 25% cover 15/5, 75% cover 20/6 and harvest 15/9.

d) stress deficit = 36mm (called "root constant" in the program)

e) PT factor $\left(= \frac{\text{PT (crop)}}{\text{PT (grass)}} \right) = 1.0$

A summary of the irrigation need as calculated by the program, together with the actual irrigation applied, and the crop's response to irrigation* is given in table 1.

* following consultation with R Bailey, Gleadthorpe EHF.

Table 1 Irrigation and Crop Response at Gleadthorpe EHF: mm

	Water Applied	Calculated Need (IPP)	Yield Response t/ha	Summer Rainfall Apr-Sept
1961	142	100	3.8	293
62	132	150	3.3	292
63	43	100	0.8	310
64	86	125	2.8	202
65	41	25	-1.0	409
66	99	100	1.3	367
67	152	150	16.1	288
68	51	50	0.5	518
69	102	100	14.8	417
70	226	200	24.8	238
71	84	50	3.5	350
72	99	75	12.6	271
73	64	25	0.8	454
74	79	100	-1.3	298
75	-	200	-	198
76	272	275	39.7	205
77	111	175	23.0	231
78	91	75	3.9	340
79	120	125	18.9	287
80	66	25	-0.8	333
Mean	108	107		315
st.dev.	59	64		86

The actual irrigation was measured by "catch-cans" in the trial and therefore is not a simple multiple of 25mm applications. After rounding that applied to the nearest 25mm and comparing the number of applications to the predicted values, it can be seen that:

in 6 years the number of applications are in agreement
in 7 years there is a difference of 1 application
in 5 years there is a difference of 2 applications
in 1 year there is a difference of 3 applications (1977).

These annual differences are not always in the same direction, so over the 19 years of comparison the mean irrigation applied was 108mm and compares to the calculated requirement of 107mm.

2. Comparison of Drainage with MORECS

Although the irrigation planning program contains some similar routines to the MORECS soil moisture balance program (Thompson, et al, 1981), the programs do differ in many major respects. Common to both programs is the assumption that all surplus moisture drains instantaneously through the soil profile - there is no facility for slow drainage.

Table 2 lists the annual totals of drainage from both programs.

Table 2 April to September Totals of Drainage under Potatoes: Gleadthorpe: mm

	IPP*	MORECS	Difference
1961	40	46	-6
62	20	25	-5
63	31	34	-3
64	0	1	-1
65	82	63	19
66	77	86	-9
67	61	75	-14
68	154	144	10
69	77	87	-10
70	35	41	6
71	44	40	4
72	19	16	3
73	144	122	22
74	0	0	0
75	1	8	-7
76	0	0	0
77	16	22	-6
78	28	24	4
79	76	77	-1
80	53	38	15
Mean	48	47½	

* the IPP was run without the option of actually applying irrigation.

With no irrigation actually included in the long term plan the annual drainage values can be compared directly with those from MORECS. Again the averages over the twenty year term agree closely, but in individual years the differences in this example varied between +22mm and -14mm. The largest differences tend to occur in the wetter summers when the long term irrigation plan produces larger drainage estimates. Because the soil moisture balance model in the IPP is not specifically designed to handle prolonged periods of moisture stress (where as the MORECS model does), then the assumption is made that the MORECS values more closely reflect field conditions.

The level of agreement is none the less reasonable and therefore we can be confident in comparing relative differences in drainage under some common irrigation plans from the point of view of leaching of nitrates: see table 3.

Table 3 Calculated Drainage (mm) Under Irrigated Potatoes

	No Irrigation	25mm @ 25mm SMD	25mm @ 35mm SMD	Irrigation for Scab Control*
1961	40	74	51	76
62	20	73	34	42
63	31	90	84	85
64	0	2	0	0
65	82	131	106	115
66	77	135	91	103
67	61	61	61	62
68	154	246	201	225
69	77	151	126	155
70	35	73	52	51
71	44	133	87	102
72	19	64	39	36
73	144	168	144	174
74	0	41	20	35
75	1	7	1	19
76	0	44	30	36
77	16	42	42	48
78	28	79	87	88
79	76	95	76	98
80	53	80	68	77
Mean	48	89	70	81
st. dev.	44	58	49	55
5th highest in 20 years	82	134	108	123

period of irrigation 1 June to 30 August
*for scab control: 12mm @ 15mm SMD 1/6 - 15/7
25mm @ 35mm SMD 16/7 - 30/8

Clearly, in particularly wet summers, as 1968 and 1973, irrigation considerably increases the amount of drainage, and by implication leaching of soil nutrients, and some plans are noticeably worse than others. Note also the differences in more "normal" summers ie 1966 and 1971.

Output Statistics

The requirements of an adviser using the planning program can be many and varied. Most simply a total water requirement (possibly split into monthly amounts) may be needed for a water extraction licence application or a reservoir design calculation. Alternatively, pump capacity at peak times, supply pipe sizes or cycle times between applications may be obtained. Most commonly the irrigation need, per crop, during the fifth driest year in twenty will be calculated as the standard design criteria. All this information is available from the program's output but it is not readily extractable from the simple statistics presented.

Statistically it is preferable to calculate design irrigation requirements from the mean and standard deviation of the annual need, rather than to produce a figure by simple inspection. From normal distribution tables we can state that, for example, the 5th driest year in 20 will equate to the 78th driest in 100, and statistically this equals the mean value plus 0.772 standard deviations, ie mean = 100mm, population st. dev. = 40mm, then 5th driest year in 20 requires 100 +0.772 (40) = 131mm*.

Similarly we can state that:

the 10th driest year in 20 is	0.075 SD's above the mean
9th	0.202
8th	0.332
7th	0.468
6th	0.613
5th	0.772
4th	0.954
3rd	1.175
2nd	1.476

* Conversley the 5th wettest year in 20 requires 100 - .772 (40)
= 69mm

A table containing these statistics if included as part of the routine output would save considerable time in interpretation.

A further table which would be of value would detail the monthly water requirement, each year, in the form:

	April	May	June	July	Aug	Sept
1961						
62						
"						
"						
"						
"						
Total						
Mean						
St. Dev.						

The table should be produced per crop in addition to a total for all crops combined. as there is a requirement from the Water Authorities for an estimate of monthly need when applying for an extraction licence.

Discussion

There are several areas where the program could be improved.

1. Period of run

The 1961-80 period normally produces a mean average annual rainfall which is close to the 1941-70 average, but there are areas in the country where the differences are greater. The misconceptions in yield response which can arise from basing irrigation advice on a non-representative period have been detailed by Bailey (1986).

Additionally an adviser or grower would identify with data from more recent years and further verification could be made against more recent trials work.

The dataset should be updated periodically.

2. Input database

Presently only the 150 stations on the "Agromet" dataset (Field, 1983) can be used in the planning program. This may be adequate for the calculation of evaporation rates (although coastal sites may cause problems), but the crude correction factor for rainfall which tries to adjust met. site rainfall to reflect average farm values is generally unsatisfactory, especially with showery summer rain. This approach fails to utilise a database which should be one of the main strengths of the program - namely the database of 5000 daily recording rainfall stations covering the whole of the UK, and likely to be the source of rainfall data within 5km of the farm. Access routines should be included which allow this database to be incorporated.

3. Soil Specification

The bands specifying low, medium and high available water capacities are arbitrary and, in the case of medium AWC's, extremely large. For instance, "medium" covers soils ranging from sand through to silty loam, and the average AWC for the range is 17.2% by volume. There is no reason why each soil could not be identified by its % AWC (which would also enable soil packing densities to be considered), current values of which are available from Soil Survey or ADAS Soil Science departments. The "Irriguide" daily irrigation planning program has already successfully incorporated this idea.

4. Crop Specification

The concepts of "root constant", and factors which adjust the PE (grass) value to approximate to other crops, are now outmoded. The physiologically important crop parameters, height, leaf area index and rooting depth are now well defined (in Irriguide and elsewhere), so that accurate default values can be suggested for a very wide range of crops. After the emergence date, daily increments for crop development should be

incorporated to replace the present stepped system, which is a carry over from the balance sheet approach. As a further refinement, a simple crop/weather model could be considered to calculate soil moisture conditions and temperatures, and the target planting date advanced or retarded by say 10 days to simulate early or late seasons.

5. Drainage

Past systems (including MORECS) assume that drainage (or runoff) occurs instantaneously through the soil profile. This is clearly incorrect and more recently the Irriguide program has been written to permit a temporary phase during which a soil holds moisture above it's field capacity value (ie a negative soil moisture deficit). This more realistic approach will reduce the seasonal totals for drainage by allowing some of the surplus moisture to be lost by evapotranspiration. It will also decrease the annual irrigation requirement.

6. Trickle Irrigation

Currently this cannot be accurately calculated and for many horticultural applications it limits the use of the program. Because a daily water balance is performed in the program then the inclusion of a daily trickle irrigation requirement is a small extra step. A different form of output statistics may be required for trickle irrigation.

7. Irrigation Statistics

These should be considerably improved - as discussed earlier.

8. Crop Response to Irrigation

MAFF have a commissioned project nearing completion to detail the response of several arable crops to applied irrigation. Further information, which can be used with varying levels of confidence, is contained in MAFF Reference Book 138 (MAFF 1982).

An annual agronomic dataset is to be produced detailing crop response which could be interfaced with the long term irrigation planning program to produce a cost/benefit calculation for any given irrigation plan. This is still at an early stage of development so it must be viewed as a longer term objective.

Conclusions

In it's present form the long term irrigation planning program is a useful and versatile tool. The predicted irrigation need for main crop potatoes is in reasonable agreement with experience at Gleadthorpe EHF over a long period, although there are sometimes large differences in individual years.

It's simplistic approach to cropping and soil moisture modelling, together with a lack of verification data, indicates that there are several areas where improvements could be introduced. Certainly better use should be made of the vast database of daily rainfall records held at Met. Office headquarters.

To date the program has not been actively marketed by ADAS arable and horticultural advisers. Following the success of the ADAS/Agromet Irriguide program these marketing avenues are now more apparent, and an improved long term planning program would compliment the Irriguide program, to offer the most comprehensive service.

The inclusion of all or some of the above recommendations would be necessary before active marketing could be undertaken with complete confidence.

Runs of the long term planning program or details of the Irriguide Service can be obtained from the Regional AgroMet. Officer.

Any comments or suggestions should be addressed to the author.

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